The Evolution of HAZARD, the Fire Hazard Assessment Methodology

Walter W. Jones

Fire Modeling and Applications Group
Building and Fire Research Laboratory
National Institute of Standards and Technology

Abstract

The United States alone spends about $700B per year on new and renovated construction. About 20% of this is to assure safety from unwanted fires, which includes the cost of insurance, to make families whole after fires and to recover from business loss. This is an enormous cost to endure every year. Combined with a growing construction market in other countries, this presents a major opportunity for the introduction of new fire safe products to the building and transportation industries and new products such as advanced detectors and suppression systems and fire fighting equipment for the fire protection industry. The intent of performance based standards is to provide flexibility in maintaining accepted fire safety from unwanted fires with new competitive products while providing an opportunity for saving lives, reducing property loss, at the same time buying a reduction in the cost of design, construction, maintenance and liability coverage. In order to derive this benefit it is necessary to have tools to evaluate building systems performance which then provide a metric for the effectiveness of design and material use. The methodology embodied in HAZARD I is intended as a tool to aid in understanding the consequences of unwanted fires. The intention of the Hazard Methodology is to make available the research that is done in pursuit of this goal. Improvements will include increased applicability of the current procedure, improved usability, the ability to address additional building features, and more accurate treatment of the fire itself and the effects of the fire on people and their actions. Many improvements have been made in the documentation which accompanies software as it has evolved. These improvements are a result of the experience fire protection engineers and others have had in using the methodology. The experience gained by having HAZARD I widely used, concomitant with the improvements which are now being incorporated constitutes the first step in the overall goal of a complete Fire Hazard Assessment Methodology.

Key words:

Fire Modeling, building design, fire growth, smoke movement

Introduction:

The United States alone spends over $700B per year on new and renovated construction. About 20% of this is to assure safety from unwanted fires, which includes the cost of insurance, to make families whole after fires, to recover from business loss and so forth. This is an enormous cost to endure every year. Combined with a growing construction market in other countries, this presents a major opportunity for the introduction of new fire safe products to the building and transportation industries and new products such as advanced detectors and suppression systems and fire fighting equipment for the fire protection industry. These industries need measures of performance for their products and mechanisms to show that these products can be safely and quickly introduced. Performance based fire standards are currently under development to augment prescriptive standards around the world. The intent of performance based standards is to provide flexibility in maintaining accepted fire safety from unwanted fires with new competitive products while providing an opportunity for saving lives, reducing property loss, at the same time buying a reduction in the cost of design, construction, maintenance and liability coverage. In order to derive this benefit it is necessary to have tools to evaluate building systems performance which then provide a metric for the effectiveness of design and material use.

In order to move to performance codes and standards, it is important to include all those involved in the decision making process, from local officials, to the model code organizations, to the professional societies, to those who develop the methodologies. It is important to demonstrate that performance based standards will provide a higher level of safety as well as reducing barriers to the introduction of new technologies and products. The Fire Hazard Assessment Methodology provides the first component of a performance evaluation system.

The Hazard Methodology[1] is intended as a tool to aid in understanding the consequences of unwanted fires. The primary intention of the Hazard Methodology is to make available the research that is done in pursuit of this goal. At present, there is a prototype of the methodology, known as Hazard I.

The scope of this prototype, its data base and the example cases are focussed on single family residential occupancies. The primary limitation is the rule-set used in the egress model rather than inherent limitations of the fire model. Improvements will include increased applicability of the current procedure, improved usability, the ability to address additional building features, and more accurate treatment of the fire itself and the effects of the fire on people and their actions. As with codes and standards, the choice of what is to be included in each step of this improvement process is a consensus amongst of the users of what is most important. The goal is to make fundamental research available in a more timely way than if is left to diffuse out to those in the fire protection community. The hope is that the tedium associated with applying a multiplicity of formulae to solve a problem will be alleviated to some extent. This is particularly important with a field that is as complex as fire research.

The methodology consists of a set of procedures combining expert judgment and calculations to estimate the consequences of a specified fire. These procedures involve four steps: 1) defining the context, 2) defining the scenario, 3) calculating the hazard, and 4) evaluating the consequences. Steps 1, 2, and 4 are largely judgmental and depend on the expertise of the user. Step 3, which involves use of the extensive HAZARD I software, requires considerable expertise in fire safety practice. The core of HAZARD I is a sequence of procedures implemented in computer software to calculate the development of hazardous conditions over time, calculate the time needed by building occupants to escape under those conditions, and estimate the resulting loss of life based on assumed occupant behavior and tenability criteria. These calculations are performed for specified buildings and fire scenarios of concern.

The centerpiece underlying all of Hazard I is a zone model of fire growth and smoke transport. The Hazard Methodology surrounds this with models of egress and tenability, auxiliary computer codes, databases and tables to enable efficient use of the model. The software is evolving in several directions. These include increasing the scope of the physical phenomena which are modeled, additional behavior rules and more flexible computing capabilities. The first release of the methodology was Hazard I, version 1.0, in the Summer of 1989. Hazard I version 1.1 was released in the spring of 1992. Version 1.2 was published in the spring of 1994. Many improvements have been made in the documentation which accompanies the software. These improvements are a result of the experience fire protection engineers and others have had in using the methodology. The experience gained by having Hazard I widely used, concomitant with the improvements which are now being incorporated constitutes a true Fire Hazard Assessment Methodology. It is difficult to overestimate the impact that HAZARD is having on the fire protection community. It is accepted in liability adjudication, criminal proceedings, building code exceptions and so on.

History:

Over the past decade the fire program of the Building and Fire Research Laboratory (formerly the Center for Fire Research) has developed computer based models as a predictive tool for estimating the environment which results in a building when a fire is present. In the beginning, there were three of these models: FAST, FIRST and ASET. In 1985, development of the CCFM (Consolidate Computer Fire Model) was begun. It was originally intended to be a benchmark fire code, with all algorithms of fire phenomena available for experimentation. A change in direction was made in 1986 and it was subsequently developed as a prototype of a well structured model. In 1989, a decision was made that development of many computer programs was not the best possible course. Two programs resulted from that. The two were CFAST and FPETool.

CFAST is intended to operate on many platforms, be as error free as is humanely possible, be simple to run for simple problem, yet allow complexity where needed. The code is extremely fast. It is faster than any code of comparable completeness and complexity. It works on laptop personal computers, Unix workstations and supercomputers. It provides for extensive graphics for analysis with pre- and post-processing modules. It is extremely fast on single compartment cases, and with the data editor, there is tremendous flexibility for parameter studies, "what if" testing and so on. It is intended to be a complete, yet very fast, computer code for calculating the effects of fire on the environment of a building. It is particularly well suited for doing parameter studies of changes, both subtle and large, within a single compartment.

The phenomena developed over the past couple of years constitute the endpoint for Hazard 2.0. These include new phenomenon and features as appropriate to continue the tradition of providing a state-of-the-art tool for hazard analysis for use by fire protection professionals. They fall into four areas: fire model, egress and tenability models, databases, and user interface and documentation.

The FPETool project was carried through as a basic DOS based text package until there was a paradigm shift in the fall of 1995. At that point it was determined that a better user interface was needed, and the “fire simulator” fire model was replaced by an interactive version of CFAST. The new user interface (a graphical user interface or GUI) was developed to ease the use of this and subsequent fire modeling tools. This is called FASTLite and is the prototype for future versions of CEdit and Hazard. FASTLite replaces FPETool with a more robust and complete fire model, as well as incorporating enhanced versions of the FireForm modules.

Overview of recent changes to the software:

This section discusses the changes which have occurred in the various modules which constitute the HAZARD package. The discussion is focussed on those who use the components of the package individually, but everything that is stated applies to the combined HAZARD package. The most obvious change is that we have converted most of the programs to extended memory. This has several implications for use of the package. The first is that a 386/486/P5 processor is required, and a minimum memory configuration of 4MB is needed. This has allowed us to increase the number of interior compartments to 15.

There are a number of additional phenomena which have been added, based on this increased capability. For example, we have implemented a ceiling jet algorithm[2] which takes into account heat loss from a fire placed in an arbitrary position within a compartment. The algorithm describes the theory and implementation of the algorithm which accounts for the off-center placement of the fire and its effect on heat transfer to the room surfaces. Implementation of this algorithm demonstrated the importance of detector siting and sensitivity on detecting the presence of fire. We hope to be able to continue this work to include smoke and heat detectors in the model so that such studies can be conducted in a systematic manner, both for within compartment detection, as well as remote detection, that is for detector siting in adjacent compartments. At present, the fire must be specified. The next phenomenon to be included will be a pyrolysis and flame spread algorithm. The necessity lies in being able to treat wall linings, mattresses and cable trays properly. A requirement to implement such an algorithm will be to improve the radiation model discussed, which is discussed later. Finally, a general radiation model is now used. This is a ten wall model for the four upper wall segments, four lower wall segments, ceiling and floor. Numerically it is simplified to four segments, based on symmetry of the rectangular parallelepiped used in our zone model[3]. It is just slightly slower than the earlier extended ceiling algorithm, but the improvement in accuracy is significant[4].

The Exitt (sic) and Tenab modules have been combined into a single entity called Survival. The salient difference in Survival is that incapacitation or death will prevent further movement of a person. The original thrust of Exitt and Tenab, which allows one to see relative effects of toxic insults, will be incorporated into Survival. At that point we will no longer includve the Exitt and Tenab modules in the HAZARD package.

Phenomena which are now incorporated into the fire model:

Multiple compartments (currently 15, proposed 30),
Multiple fires - specify with "other" objects,
Vitiated or free burn chemistry in the lower layer, the upper layer, or in the vent flow,
Consistent production and transport of species,
Simple flame spread (vertical and lateral),
Four wall and two layer radiation,
Four wall conductive heat transfer through multilayered walls, ceilings and floors in each compartment,
Conductive heat transfer through barriers (ceiling/floor conduction),
Convective, and radiative heat transfer applied to both inside and outside boundaries,
Wind effects included - ASHRAE formula for wind with the NOAA integral for lapse rate of the standard atmosphere,
Fire plume and entrainment in vent flow (doors and windows only): Fire plume is split into the entrainment in the lower layer and the upper layer,
3D specification of the location of the fire and non-uniform heat loss thru boundaries,
Generalized vent flow:
    Horizontal flow (doors, windows and so on) - up to three neutral planes
    Mixing between the upper and lower layers

Vertical flow (through holes in ceilings and floors),
Mechanical ventilation
Separate internal and external ambient (elevation, temperature and pressure specification),
HCL deposition,
Detection - smoke or heat, and
Suppression - 0th order by water (no geometry effects)

While the usefulness of some aspects of the way the data input is structured may not be apparent, it is important to present information, and choices, it the context in which people who use these tools speak. So while it is possible to use an effective k,ρ,C for arbitrary wall structures, those who deign and build structures think in terms of the components, for example.

Egress and Tenability Model:

The project to develop a quantitative hazard assessment method was initiated following the NBS Workshop of Combustion Product Toxicology held in 1982 [5]. In this workshop, papers were presented in which some of the initial concepts of hazard analysis were discussed. The general approach for the hazard analysis capability was discussed in the "Journal of Fire Science" early in 1983 [6]. Later that year, NBS made a commitment to produce a practical hazard assessment method in 3 to 5 years [7]. HAZARD I and the accompanying software and documentation is a prototype of this method [8],[9], and [10].

EXITT models the evacuation process of occupants in a building exposed to a growing fire. EXITT is a deterministic model that uses the layer height and smoke density data from CFAST along with a set of behavioral rules to predict the actions of each occupant. Based on an occupant's action, the program determines the occupant's destination. The program then determines the shortest "safe" route to arrive at the destination. When an action is completed, the occupant is assigned a new action and the process is repeated. The program ends when all occupants are either out of the building or unable to perform any additional actions.

TENAB estimates the hazard, as determined by a set of tenability measures, to which each occupant is exposed as he performs his designated actions. TENAB uses the occupant time and location data from EXITT in conjunction with the environmental data from CFAST to determine the tenability conditions for each occupant or compartment. When a measure exceeds a certain level the occupant is considered incapacitated or dead.

Limitations: There are phenomena which can be improved:

- *General* - Pyrolysis (and flame spread) models still depend on test methods, no heating/cooling in HVAC ducts, and reverse flow in fans is not allowed

- *Entrainment* – fire plume and doorway jet entrainment are based on the same experimental correlations. The fire plume (for large spaces) and the doorway jet (in general) are often used outside the normal range of validity of these correlations.

- *User specification* – the level of agreement is critically dependent upon careful choice of the input data for the model. A better understanding of typical fire induced leakage in buildings would facilitate more accurate description of the building environment.

- *Statistical treatment of the data* – presentation of the differences between model predictions and experimental data in are intentionally simple. With a significant base of data to study, appropriate statistical techniques to provide a true measure of the "goodness of fit" should be investigated.

- *Experimental measurements* – measurement of leakage rates, room pressure, or profiles of gas concentration are atypical in experimental data. These measurements are critical to assessing the accuracy of the underlying physics of the models or of the models ability to predict toxic gas hazard.

Overview of the Future:

As the hazard methodology is improved, there are four avenues to follow: Increase the number and improve the capability of the phenomena which are modeled, Improve the usability of the package, Provide derivative applications, and Expand the scope of the use of the methodology.

As the concept of fire safe structures takes hold, the question will arise of how much does some improvement cost, how much will it save, and what are the likely actions of those involved in a fire. One area we have not discussed explicitly is the valuation of a building or system subject to a fire, and what the worst or most probable fire and concomitant dollar loss would be. Such a capability would be on top of that for estimating the effect of fire.

HAZARD is now published with some sample cases, but it would be beneficial to enhance its use by providing a set of cases from start to finish with a data file and a video of an actual case being burned. We could have a presentation of fire and its consequences. This might include (computer) video and concomitant data sets for simulation.

The concept of general building/people/fire interactions should be included. There are three aspects which could be addressed. The first is the people/building interaction. The second is an integrated model for commercial, industrial and residential rules. The third is an editor for people movement rules. The fire model is sufficiently fast that the run time graphics is almost irrelevant. It should be possible to develop Survival so that the people interact with the fire by having Survival call the CFAST kernel.

The front end graphical user interface (GUI) for CFAST/Hazard v2.0 should be an improvement over the text based interface we currently utilize. The intent is to extend this to all aspects of modeling, including the use of the FireForm idea as a utility within HAZARD. Our concept of a GUI was first embodied in FASTLite and the CFAST shell. In the first instance, we will have a simple single file editing session. The long range plan is to allow editing of multiple sessions and concurrent execution of the model. In some ways this goes beyond our original goal of providing a simple filter to prevent egregious mistakes, but it will allow us to make the databases much more versatile without encumbering those using the methodology too much. We will extend the editor to include the graphics output as well as the people placement and specification of those items which affect the behavior of people. The new GUI's will present a graphical two dimensional representation of a building. Also under development are computer aided design (CAD) based input and output displays. These improvements should aid in encouraging the use of these models by architecture firms and others not conversant with fire problems, but intimately concerned with buildings.

An important extension of the hazard methodology would be the concept of automated parameter variation, which includes incorporating probability of actual events to ascertain the relative effect of particular scenarios. This capability will increase the usefulness of our models many fold. As part of this work, we will develop a mechanism to ascertain the sensitivity of the outcome to the parameters themselves (fine variation) as well as their variation (gross variation). A critical point will be to decide upon a reasonable extent of variation. For example, if we consider a door that will be open or closed, should we consider it to be absolutely closed, with leakage, a crack ⅛, ¼, ½ and fully open, or some other combination?

New phenomena needed for the fire model: There are many new phenomena which we need to incorporate. Those under active consideration include

Compartment to compartment heat transfer via heat conduction,
Flow within compartments,
Burning at corners (furniture, adjoining walls),
Structural effects (barriers to smoke and fire spread as well as load bearing capability),
Improved pyrolysis model (based on more fundamental physical aspects of materials),
Construction design files (databases used for building and ship design),
Self consistent fire - both a flame spread model and a pyrolysis model,
Improved understanding of species generation such as CO/CO_2 and its source,
Two directional heat transfer in walls (non-congruent thermocline),
Better detector and other sensor activation (include new detectors),
Deposition and agglomeration of smoke and other species,
Suppression - include fire size, drop size and distance effects, geometry of the fire, evaporation/cooling
Modifications to all modules to utilize FDMS[11],[12] databases,
Corrosion - add on for HCl - important for semiconductor industry and warehouses.
Smoke movement in tall shafts, stairways and atria

Databases: An important part of our work is developing into providing various types of databases. This is an important underpinning of the cooperative venture. Companies will be able to make decisions on products or building assemblies. At present we are redoing the FDMS concept. There are two reasons: 1) it is very difficult to add new types of tables. This has resulted in many people abandoning its use; and 2) for the fire modeling work we need a consistent and well defined database structure for data which is used for validation, the various data sets we use within the models, and so on. We are developing the new structure and modules with the caveat in mind that previous work should fit into and be usable. We now deliver HAZARD with some sample cases. It would be beneficial to those unfamiliar with this tool to be able to run through a set of cases from start to finish with a test case, a video of the actual case being burned. If we begin to develop this now, perhaps with cooperation from anyone doing full scale tests, we could have a very nice presentation of fire and its consequences; we could include (computer) video and concomitant data sets for simulation.

New Technology: Technologies which we should address and embrace include the diversity of computer platforms which are evolving, networks and multiprocessor systems, and new hardware such as CDROM. Using CDROM technology will allows us to include the databases which will be necessary to utilize the new generation of fire models. In addition, we can include video sequences of some of the sample and test cases. We need to run actual fires of some of the samples files which we distribute with HAZARD and include the video with the distribution.

At present there are over 100 million microcomputers in use. This number, including high end workstations, is likely to continue to increase. Manufacturers are beginning to develop small-scale parallel systems, and the cost of adding a processor board is only about 20% of the cost of a new system. The implication is that 2 to 10 processor systems are likely to become the norm for computer systems. Also, office systems are being networked. This is especially for those people we are trying to reach, who have both homogeneous and heterogeneous systems. We should be able to take advantage of these hardware configurations. This utilization will become more important as the models become more complex and there is a concomitant increase in the computing time. We will begin developing a method to utilize this parallelism.

Capabilities and Processing Power: For real time fire fighting, we could have a portable computer (hand held) which allowed one to walk through a building (before or after) and catalog the contents of a building. This could be brought back to the office and used directly as input to the model for geometric specification and data initialization. As the Cellular Digital Packet Data becomes more prevalent, onsite inspections will allow such handheld computers to interact directly with desk bound servers for maintaining databases and ascertaining code compliance. As the model becomes more sophisticated, and the complexity increases, researchers, code officials, and everyone else will have to depend on such stratagems. There simply is not enough time to fuss with all of the details. This is the arena which should allow us to pursue the goal of a better qualitative understanding of fires, well as doing more of it faster.

All large buildings have annunciator panels for various alarms. Indeed, some fire departments can display floor plans of buildings in the command center at a fire. It is a logical next step to plug these displays into the alarm system to see the current status of a building and then make a prediction of the next five minutes. At present, there is not sufficient information available at these sites to implement such a concept, but as buildings become "smarter" and sensor rich, such a path will seem natural.

Extension to Risk Assessment: Another area is that of risk. Risk is the next step up from a hazard calculation, and requires a much more general understanding of the parameters which affect the outcome of a fire and its impact on humans and structures. This application would require an automated application of the model over types of fires, day and night scenarios, position of the fire and so on. The number of such calculations can become enormous. Some means of doing this in finite time will need to be found. Also, in order to provide performance evaluation tools, it is necessary to know how often something does not happen, as well as what to do when a catastrophe occurs. An important aspect of developing a risk tool will be a means to winnow the number of calculations that must be performed in order to accomplish a study sufficiently quickly that it retains its value.

As we extend the capability of the zone models, we are encountering the inherent limitations of these types of models. The general concept of a zone or control volume model uses a volume as one of the variables. Inherently there is no spatial information available. The first deviation from this viewpoint was the necessity of including height vs. width information in order to calculate flow through a normal vent, such as a door. The second came when flow through a ceiling/floor opening and mechanical ventilation were included. We have extended the concept for the position of the fire. We must now take one more step and define the spatial component of a compartment.

Usability: The automatic transfer of information from one set of calculations to another is important to avoid unnecessary errors and repetitive data entry. The quest is to provide a tool which will aid rather than hinder. This is not an attempt to make the application of such methods trivial, but rather to provide a mechanism to allow researchers, fire protection engineers, code officials and so on access to the most current understanding of the behavior of fires. To reach this goal, we try to improve the physical basis of the model. That is the "model improvements" section below. At the same time, we hope to allow more extensive calculations, such as long corridors, three dimensional effects and so on. This is the "capabilities and processing power" section, and deals with faster computers, distributed processing, automatic transfer of data and a more intuitive interface. Finally, we have the human factors aspect. How much does fire really cost? Since our knowledge of a situation is not perfect, what range of results might one expect given a most likely scenario. This is the "human factors and cost."

Feedback from those who use such tools is crucial to the process of identifying the most needed changes. Through this process, research priorities can be established to address the needs of the community in the most efficient manner. In addition, we challenge the research community to review and comment on this effort. The gaps in knowledge identified herein can then help guide their work toward resolving these issues. The obvious conclusion is that our understanding of fire is imperfect. As we continue to plumb the depths of this problem, both the direction and scope of the methodology will be influenced by what users say is needed as well as the results which evolves naturally from the Center's research efforts.

Improvement in Egress and Tenability Modeling: Four areas of improvement exist for these two programs: consolidation, data input, data display, and expansion. It should be understood that these two models rely on an existing body of research information. Only through changes in our understanding of human behavior and survival in a combustion product loaded environment can we make meaningful alteration to these models. The major activities in this task are:

1) consolidation of the egress and tenability models - this has been accomplished,
2) consolidation of the input structure of this combined model with the fire model,
3) development of a "rule processing engine" for the egress model to allow the program to respond to different sets of rules for human behavior,
4) enhancement of the input and output displays of the program,
5) development of rules for the new "rule processing engine" based upon the current set of egress rules in

EXITT and (depending upon the availability of research on people movement in larger buildings) upon egress rules for larger occupancies, and

6) development of rules for the new "rule processing engine" based upon the current tenability rules

Interactive Egress Modeling: Of the concepts mentioned above, that of general building/people/fire interactions is the most intriguing. There are three aspects which we might address. The first is the people/building interaction. The second is an integrated model for highrise and residential. The third is an editor for people movement rules. The fire model is sufficiently fast that the run time graphics is not as useful as in previous releases of the models. It is generally easier to rerun the animation program to generate the original output than to try and look at it while the model is running. Thus it should be possible to develop SURVIVAL so that the people interact with the fire by having SURVIVAL call the CFAST kernel.

The Next Version of The Fire Hazard Assessment Methodology:

The focus on extending this methodology is to develop a more holistic approach to buildings as well as a more complete set of phenomena. That is, one must take the structure of the building into account. This arises in the form of inter-compartment heat transfer. The sort of idea we have is for two dimensional heat transfer through walls, vertically as well as horizontally, so that when several rooms are connected to a corridor the correct heat flux into the corridor is calculated. Also, the movement of smoke down a long corridor is of interest to many. Thus we are faced with placing compartments together and having the computer figure out what to do with them.

Incorporating a new phenomenon: Including a new feature into any model is rarely a trivial process. Even with a modular design of algorithms, significant time is required to “insert” the new phenomena. The steps below should give an appreciation for the process.

1. Study the algorithm and its associated documentation in enough detail to understand how it effects the environment of the entire model. This will allow the modeler to develop appropriate transformations of input and output variables of the module to allow the model to communicate with the module. Also, one must ascertain whether the required data is generally available. Such a determination drives the ancillary work of databases, literature,...

2. Adapt the coding of the algorithm (assuming it has been coded) to the model. This may involve changing variable names or calling sequences to be consistent with the rest of the model, adding additional input for data required by the module, or adding appropriate output to present the results of the module's calculations.

3. Test and verify the correct functioning of the algorithm. This will typically involve numerous model runs to compare with earlier results and to test the “new model” over a range of conditions. Limits of applicability, appropriate comments when these limits are exceeded and suitable action or limiting results in these cases.

4. Adapt (or develop from scratch) appropriate documentation for the module to be included in the documentation for the entire method. This involves both an editorial function to insure consistent readability of the entire model documentation and extending the set of examples provided with the model to demonstrate the use of the new feature. As part of a new phenomenon, a rationale, availability of data, and interpretation of output is necessary.

5. Examine and modify the internal structure of the model to address any new quantities that may be predicted by the module. This may include modifying additional modules which can now be made more correct or efficient as a result of the addition of the module. In addition, the supporting software may need to be changed to address additional input and output associated with the new module.

There are three levels of "incorporating" that must be addressed. In the concept of small, medium and big (or very big), we essentially address the issue of how much work needs to be done, starting from the concept that we wish to include. For example, adapting an algorithm from a research paper is not straightforward. There are implications for the range of validity, as well as usefulness. Also, we must concern ourselves with the smoothness of correlations. An example of such a problem which we recently addressed is that of plume flow. We use the correlation of McCaffrey[13]. He divided the plume into three regions, depending on how much combustion occurs in each region. As it turns out, there were discontinuities at the transition points. In some cases this would cause the solver (numerical integrator) to slow down dramatically. Further, since the phenomena must be continuous in real life, his correlations were prima fascia incorrect. The change to fix this was not large, but illustrates the some of the difficulty of making the transition from research to practice.

In researching this, a somewhat surprising finding is that architects have little interest in the three dimensional aspects of buildings. The actual fitting that must take place seems always to be placed on the construction end. This observation has shaped the vision of Hazard to consider the three dimensional effects of buildings, yet keep the interface simple.

Along the lines of keeping the paradigm simple, there is a need for quick estimates, based on realistic scenarios. That was one of the appeals of the early version of FAST[14]. It was simple to use, and it gave reasonable answers, quickly. We have evolved to a much more complex world, but sometimes the simple answers are sufficient. The appeal of FireForm is its simplistic nature. In this case, however, it is too simplistic, and often is not supportable. That statement holds because it has to be tweaked for each nuance of the physical model. As long as there is someone dedicated to doing this then it will continue to grow. However, like the Harvard code, without the original people dedicated to preserving it, it is too much of an insider's tool for new people to pick it up. However, the need still exists, and the concept is valid. We attempted to incorporate such estimates into the data editor (CEdit). We could never seem to "get around to it," so nothing came of the effort. The Hazard Shell includes the calculational procedures from FireForm.

We will begin the pursuit of some of these goals this next year. We plan to improve the numerics and the way conduction is handled. This will allow us to incorporate a more extensive two dimensional formulation in a timely way. Also, we are being asked to look at intercompartment heat transfer. Although we are likely only to be able to do ceiling/floor transfer, we should have a better idea of the physical problem involved in doing this.

It should be possible to extend the GUI concept to all aspects of user interaction, including the use of FIREFORM as a utility within HAZARD. Our concept of a GUI was embodied first in FASTLite, CEDIT and the Hazard shell. In the first instantiation we will have a simple single file editing session. The long range plan is to allow editing of multiple sessions and concurrent execution of the model. In some ways this goes beyond our original goal of providing a simple filter to prevent egregious mistakes. But it will allow us to make the databases much more versatile without encumbering the user of the system too much. We will extend the editor to include the graphics output as well as the people placement and specification of those items which affect the behavior of people. This thrust is important to allow general use by the building community.

Parameter variation and estimation of probabilities: One of the most important extensions of HAZARD I to Hazard, is the concept of automated parameter variation, which include incorporating probability of actual events to ascertain the relative effect of particular scenarios. This capability will increase the usefulness of our models many fold. As part of this work we will develop a mechanism to ascertain the sensitivity of the outcome to the parameters themselves (fine variation) as well as their variation (gross variation). A critical point will be to decide upon a reasonable extent of variation. For example, if we consider a door that will be open or closed, should we consider it to be absolutely closed, with leakage, a crack ⅛, ¼, ½ and fully open, or some other combination? Those ranges and combinations are under consideration.

Conclusions:

The goal is to provide a tool which will help improve the understanding of fires and safety from unwanted fires. This is not an attempt to make the application of models trivial, but rather to provide a mechanism to allow researchers, fire protection engineers, and others access to the most current understanding of the behavior of fires. Improvement in the physical basis of the model is the means to reach this goal. At the same time, it is hoped that it would be possible to allow more extensive calculations such as long corridors, three dimensional effects (the "capabilities and processing power" section), and the use of faster computers, distributed processing, and automatic transfer of data. Although the concept of a more intuitive interface is a goal, there really is no such thing as an intuitive user interface. Our goal is to provide a tool which aids, and does not hinder, understanding of fire effects and phenomena.

The goal of developing a building performance evaluation tools requires a concerted effort from many organizations. One such time line, and the contribution that NIST could make is

1) Develop a framework for expressing and analyzing fire safety performance requirements for buildings as a nationally accepted alternate to the current requirements.

CFAST/Hazard 2.0, FASTLite

2) Develop a prototype computer aided design system for fire hazard models which will allow architects and engineers to evaluate innovative building designs and new material applications against fire safety performance criteria. This system will allow analysis of design variations for reducing construction costs while increasing the level of safety.

Online data (CDROM and Internet)
Instantiate a consortium to draft a performance standard
Develop a model verification methodology

3) Conduct a demonstration project with local code authorities (AHJ's) on the process and advantages of the design and analysis system.

Prototype of performance evaluation system

Tool selection methodology

4) Deliver a method for estimating design safety factors, and provide guidance for establishing acceptable levels of fire risk based on societal risk decisions and a metric for the cost/benefit of various implementations.

Trial implementation with model codes - start to finish analysis of a project.

5) Demonstrate a methodology to examine performance codes.

Draft of performance methodology.

6) Field evaluation of a performance methodology.

This would achieve the goal of the whole fire safety engineering community, but to achieve it will require a concerted effort from standards organizations, engineering professional societies and building officials as well as NIST.

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